MICROPROCESSOR SYSTEM FOR INFORMATION PROCESSING WITH DIFFERENTIAL PHOTODETECTORS

Ivan Stanchev Kolev, Tsanko Vladimirov Karadzhov

Department of Electronics, Technical University – Gabrovo, Street "Hadji Dimiter" No. 4, 5300 Gabrovo, Bulgaria, phone: +359 66 801064, e-mail: karadjov_st@abv.bg

Keywords: Differential photodetectors, Photodiode, AD converter

Photodetectors are mainly divided into one-element and multielement. The group of multielement photodetectors includes differential, position-sensitive, linear and matrix photodetectors. The present paper treats differential photodetectors built with PIN photodiodes.

1. MICROPROCESSOR SYSTEM

A PIC 16F873 microconttroller with 10-bit AD converter (ADC) is used in the proposed circuit shown in fig.1. The parameters of the microcontroller are shown in table 2. Two independent differential photodetectors can be included in the circuit. The dividers obtained from the resistors R1÷R4 and the changeable resistances P1÷P4 converts the current flowing along the photodiodes of the differential photodetectors into a voltage which is passed to the inputs of the 10-bit ADC of the microcontroller. Since this voltage is proportional to the current, its value in μA is indicated on the seven-segment indicators. The upper threshold for the ADC conversion is set by the divider obtained from R5 and P5, whereas the lower threshold is connected to the load. The resistor R7, the capacitor C3 and the press button B1 are used to set up the microcontroller. A 4MHz quartz resonator is used as a clock-pulse generator. To indicate the value of the current, two double seven-segment LED indicators radiating green light VQE 24 are used. A dynamic indication is used, i.e. in a given moment of time only one indicator radiates light. Each indicator lights 5 ms. In this way the four indicators light for 20 ms totally, i.e. the restoreability frequency will be 1/20ms=50Hz. The transistors VT1÷VT4 have to be used because the current flowing along the cathode of an indicator may reach 80 mA. This value is rather high and it cannot be provided directly from one pin of the microcontroller. Each indicator will be switched on by passing high voltage level to the base of the respective transistor, i.e. the anode will be connected to the positive pole of the power supply.

The current flowing along each photodiode will be:

(1) $$I = I_D\left(e^{\frac{U}{\varphi_T}} - 1\right) - I_{ph},$$

where I_D - dark current;

U - reverse voltage on the photodiode;

φ_T - thermal potential;

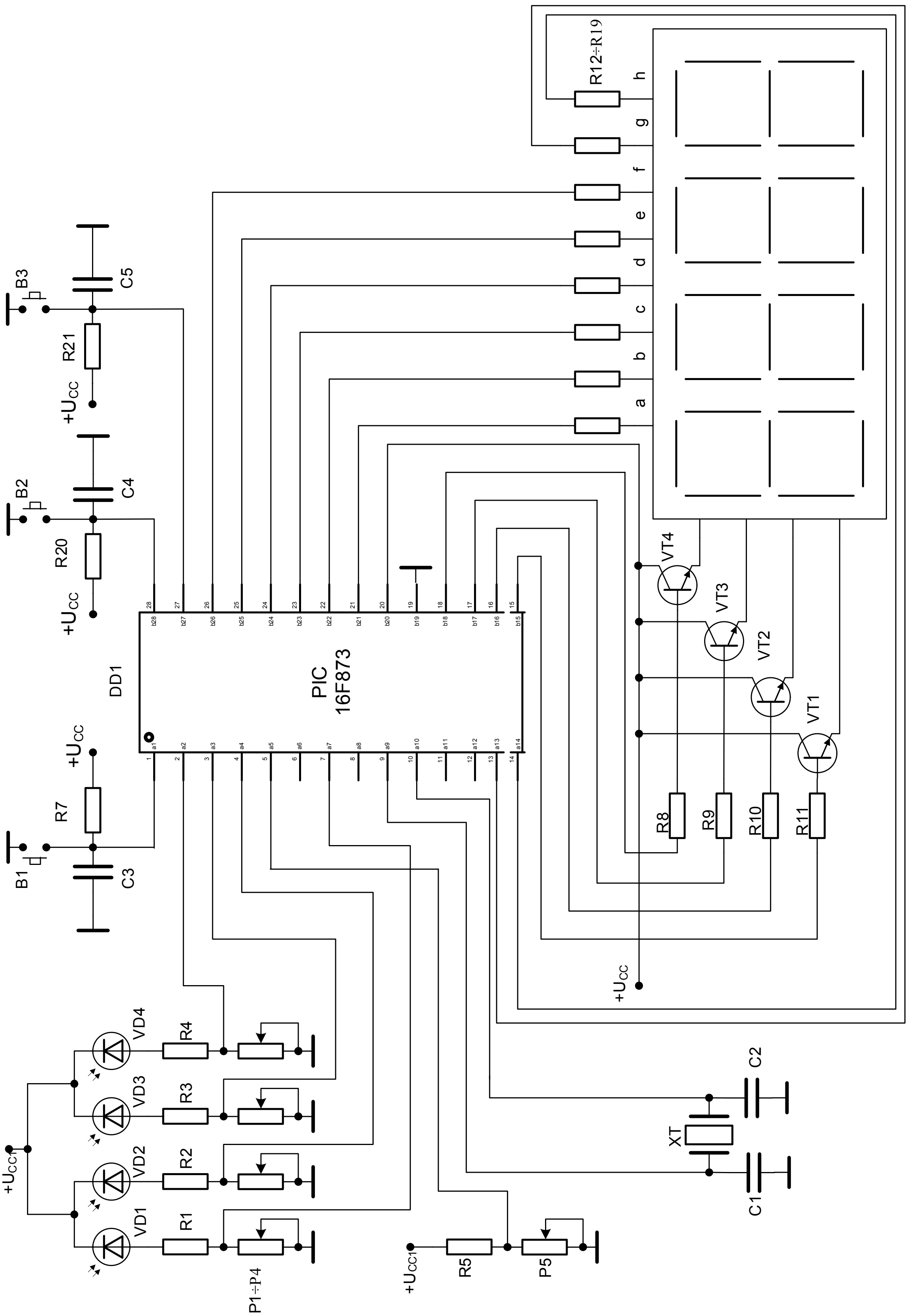
DD1
PIC
16F873
B1
B2
B3
C1
C2
C3
C4
C5
R1
R2
R3
R4
R5
R7
R8
R9
R10
R11
R12÷R19
R20
R21
VD1
VD2
VD3
VD4
VT1
VT2
VT3
VT4
XT
P1÷P4
P5
+UCC
+UCC1
a
b
c
d
e
f
g
h

Fig. 1

I_{ph} - photocurrent.

The voltage passed to the analog-digital converter is:

(2) $$U_P = I.R_P,$$

where R_P is the resistance of each potentiometer.

When (1) is substituted in (2), the following formula is obtained:

(3) $$U_P = \left[I_D \left(e^{\frac{U}{\varphi_T}} - 1 \right) - I_{ph} \right] R_P$$

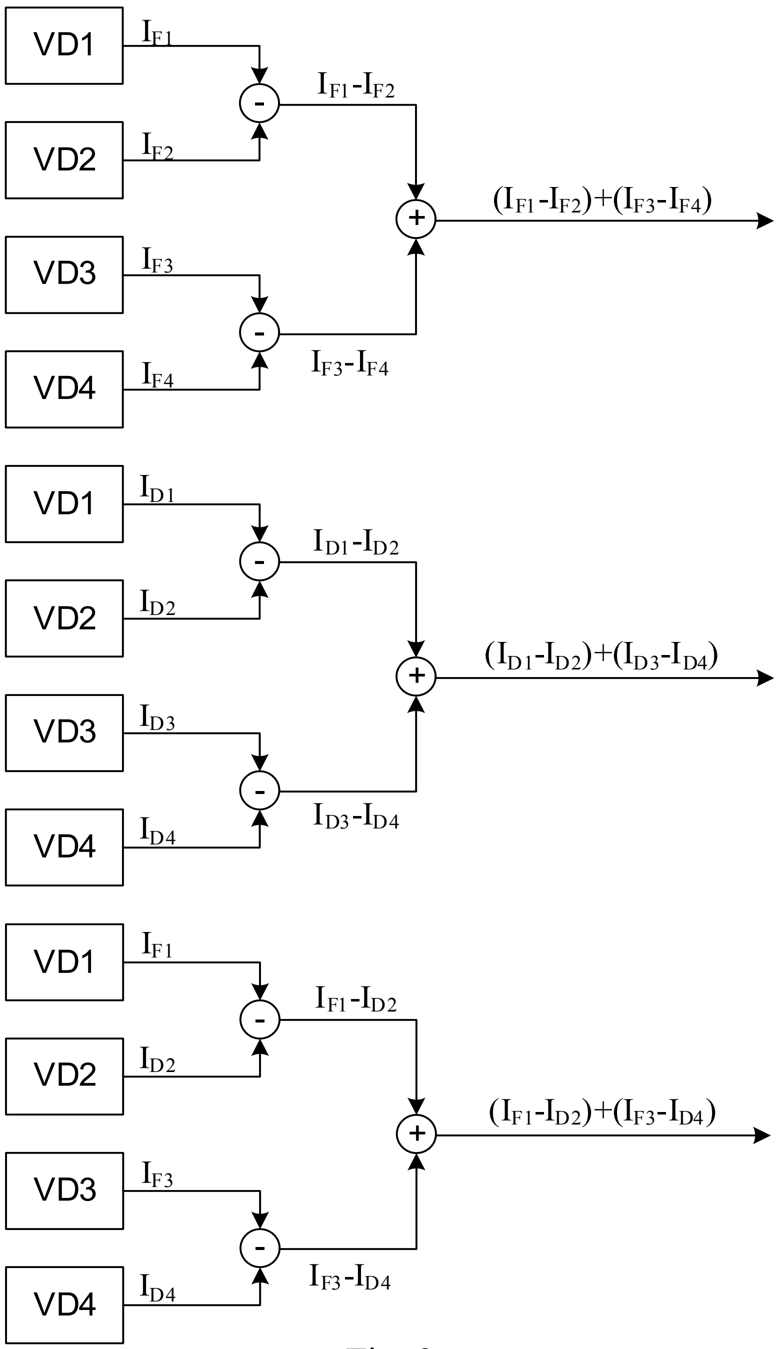

Fig. 2

The upper threshold of the ADC can be regulated and it is:

(4) $$U_{P5} = \frac{U_{CC1}}{R5 + R_{P5}} R_{P5}$$

where R_{P5} is the resistance of P5.

1.1 Operation Modes

With one of the operation modes, the value of the current of each photodiode can be indicated on the display. The photodiodes are switched manually or automatically at equal time intervals which can be changed. With another operation mode, the indicators indicate the difference between the currents passing through the photodiodes when the latter are exposed to the same illumination and temperature. In this case, this difference will depend only on the difference as regards sensitivity and the size of the PN junction. Another possibility is that one photodiode is exposed to illumination and the other is exposed to darkness.

In this way the difference between the photocurrent and the dark current of the respective differential photodetector can be determined. A model measurement sequence is shown in table 1. The measurement flow chart is shown in fig.2. These measurements can be implemented several times at different temperatures.

Table 1.

№	Participating photodiodes	Expression	Numerical value
1.	VD1	I_{F1}	
2.	VD2	I_{F2}	
3.	VD1, VD2	$I_{F1}-I_{F2}$	
4.	VD3	I_{F3}	
5.	VD4	I_{F4}	
6.	VD3, VD4	$I_{F3}-I_{F4}$	
7.	VD1, VD2, VD3, VD4	$(I_{F1}-I_{F2})+(I_{F3}-I_{F4})$	
8.	VD1	I_{D1}	
9.	VD2	I_{D2}	
10.	VD1, VD2	$I_{D1}-I_{D2}$	
11.	VD3	I_{D3}	
12.	VD4	I_{D4}	
13.	VD3, VD4	$I_{D3}-I_{D4}$	
14.	VD1, VD2, VD3, VD4	$(I_{D1}-I_{D2})+(I_{D3}-I_{D4})$	
15.	VD1	I_{F1}	
16.	VD2	I_{D2}	
17.	VD1, VD2	$I_{F1}-I_{D2}$	
18.	VD3	I_{F3}	
19.	VD4	I_{D4}	
20.	VD3, VD4	$I_{F3}-I_{D4}$	
21.	VD1, VD2, VD3, VD4	$(I_{F1}-I_{D2})+(I_{F3}-I_{D4})$	

Table 2

Parameter	**PIC16F873**
Clock frequency	up to 20 MHz
Number of pins of the frame	28
FLASH memory	4K
Data memory	192
EEPROM data memory	128
Interruptions	13
I/O ports	A, B, C
Timers	3
Modules-detection/comparison/pulse-width modulation	2
Serial interface	MSSP, USART
Parallel interface	-
10-bit ADC	5 channels
Instructions	35

1.2 Selection of a Microcontroller

To control the operation of the circuit, the microcontroller selected has to meet the following requirements:

1. Enough number of input-output pins;
2. Enough volume of memory for storing the control programme which ensures the operation of the system in its operation modes;
3. Enough informational capacity.

PIC16F873 microcontroller has been selected on the grounds of those criteria.

1.3 Block diagram of the microprocessor-based system for controlling differential photodetectors

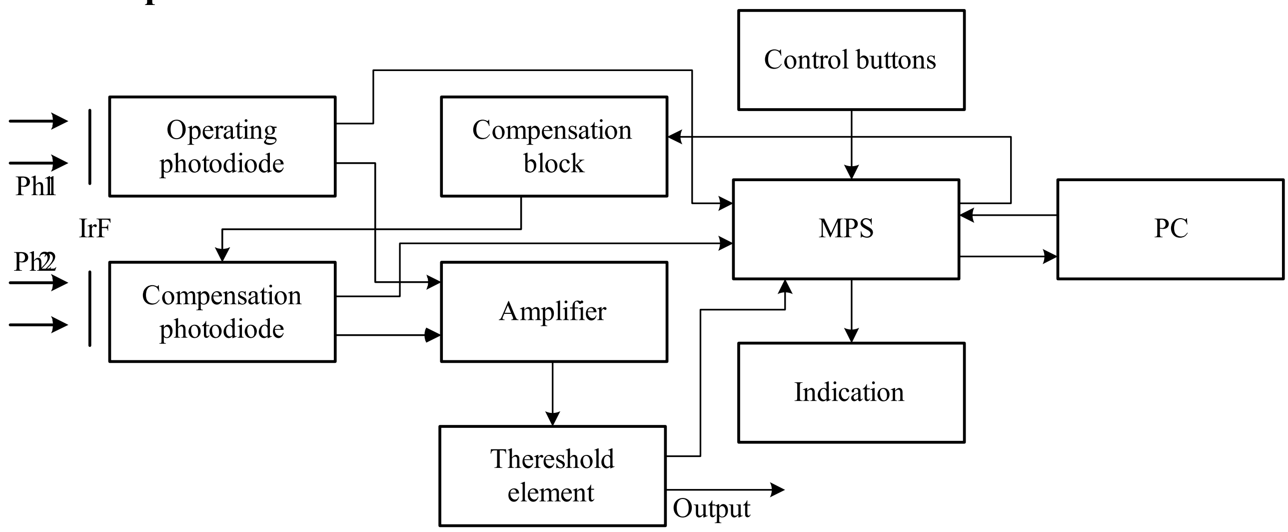

Fig. 3

The block diagram in its most general type is shown in fig.3. It contains a differential photodetector whose two photodiodes are connected to two different circuits – an operation circuit and a compensation circuit. The compensation block is controlled by a microprocessor-based system which monitors the dc-current levels of the operating and compensation photodiode. The compensation block, in turn, controls the compensation photodiode. The amplifier amplifies the difference between the photocurrents of the two photodiodes. The system can be connected to a PC. Solutions as regards decreasing the influence of the non-uniformity of the PIN photodiodes' parameters are proposed in [6].

1.4 The following parameters are proposed as criteria of non-uniformity of the electrical parameters of the differential photodetectors:

Dark current, photocurrent, switch on/off times.

1.5 Determining the Non-uniformity of the Dynamic Parameters of a Differential Photodiode

The dynamic parameters of the photodiodes mainly depend on the barrier capacity Cb and the incremental resistance R_{PN} of the PN junction. They, in turn, depend on the voltage applied to the photodiode. Then the maximal cut-off frequency of the photodiode is:

(5) $$f_{MAX} = \frac{1}{2\pi RCb\left(1+\frac{R}{R_{PN}}\right)} \approx \frac{1}{2\pi R.Cb}$$, where

R_{PN}- nonlinear incremental resistance of the PN junction;

Cb - barrier capacity;

R - low-Ohm serial resistance of the base and the contacts.

One of the ways of determining the influence of the dynamic parameters non-uniformity is measuring the barrier capacities of the PN junction, which are reversely proportional to the frequency characteristics and can be determined by means of a double-beam oscilloscope (fig.4). The photodiode is exposed to an illumination of pulse light from a uniform source.

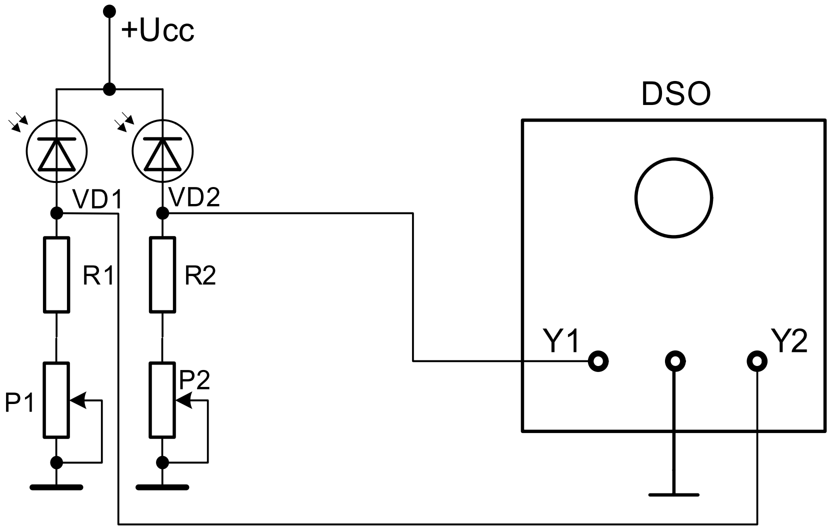

Fig. 4

2. REFERENCES

[1] Колев, И. С., *Оптоелектроника,* Трето преработено и допълнено издание, Габрово, Унив. изд. "В. Априлов", 2002.

[2] Колев, И. С., *Инфрачервена оптоелектроника,* Габрово, Унив. изд. "В. Априлов", 2004.

[3] Кенаров, Н., *PIC микроконтролери,* част 1, Варна, издателство "Млад конструктор", 2003.

[4] Колев, И. С. и Караджов, Ц. В., *Разработка и изследване на схеми с диференциални фотоприемници,* Научна конференция с международно участие, "Електроника '2004', София, 20-21.05.2004, стр. 11-16

[5] Siemens. *Si-Photodetectors and IR Emitters,* 1995.

[6] Texas instruments, *Intelligent opto sensors,* 1999.